

ANGELS, DEMONS AND ANTIMATTER



...the plot.....

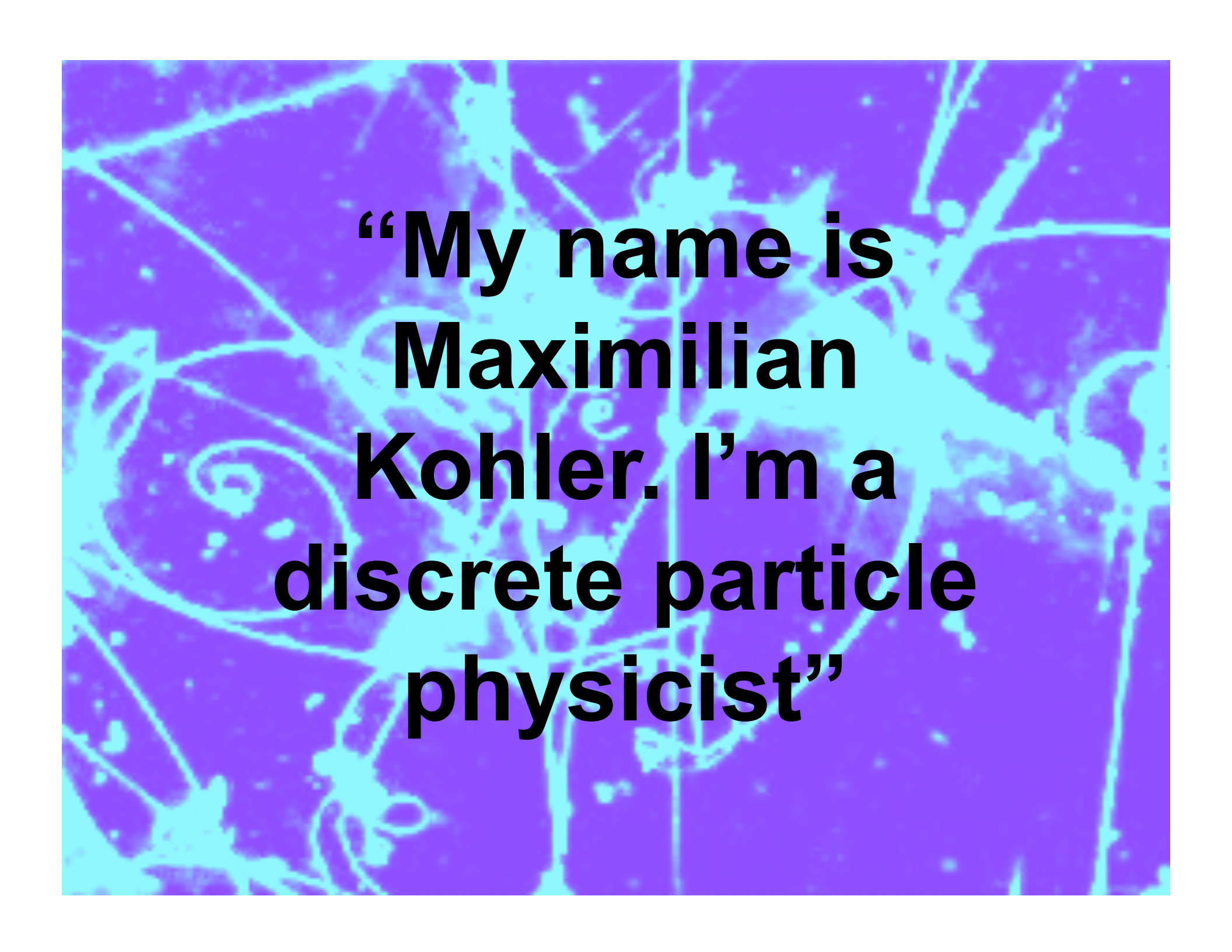
A crazy anti-religious sect murders a particle physicist and steals a canister of antimatter from the world's largest scientific laboratory in Geneva, Switzerland.

The antimatter is flown to Vatican City, in a plot to blow up the country.

A Harvard Historian and a particle physicist race to find the antimatter and get it back to CERN before the "bomb" explodes.....

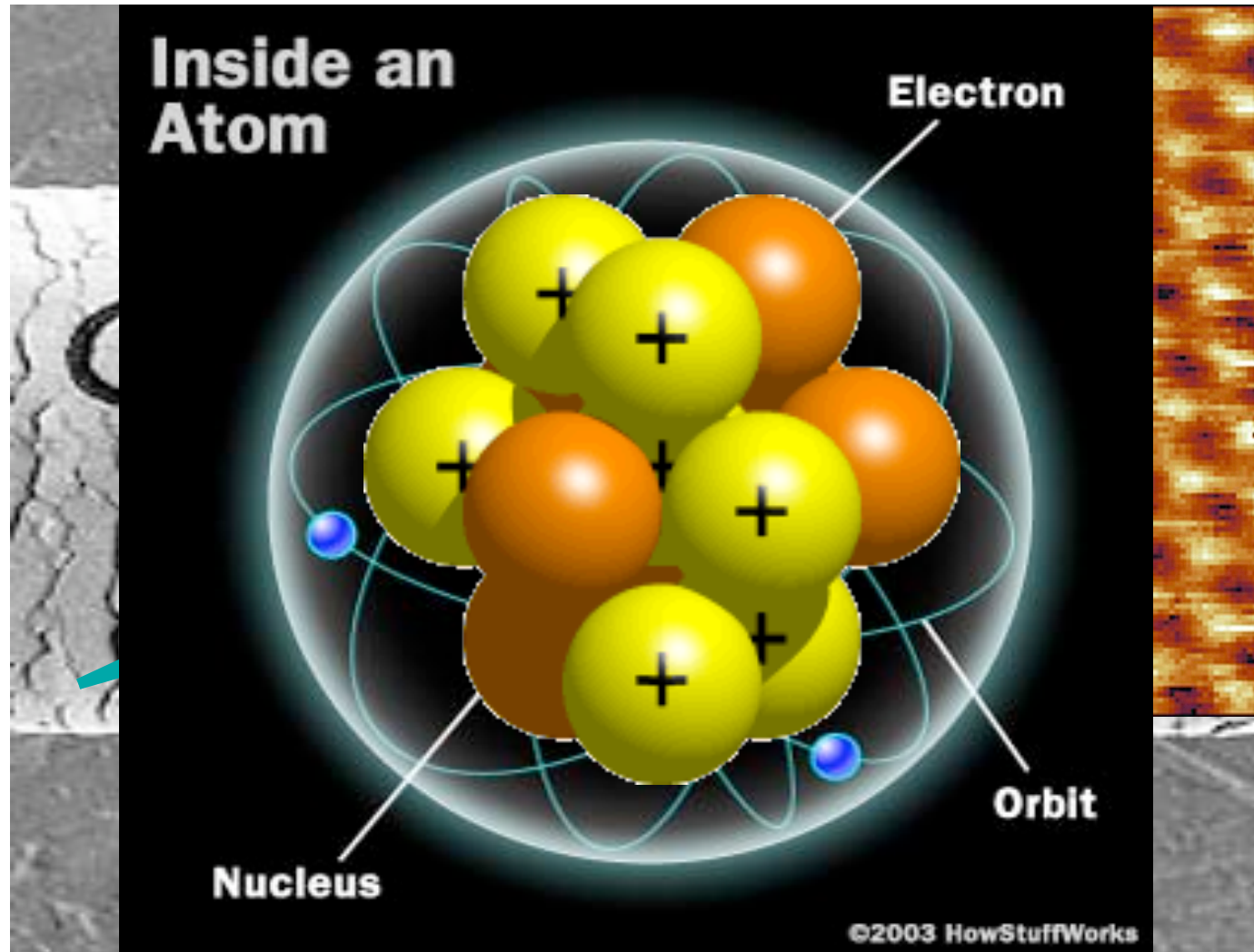
(with apologies to Dan Brown!)





**“My name is
Maximilian
Kohler. I’m a
discrete particle
physicist”**

So what is particle physics?

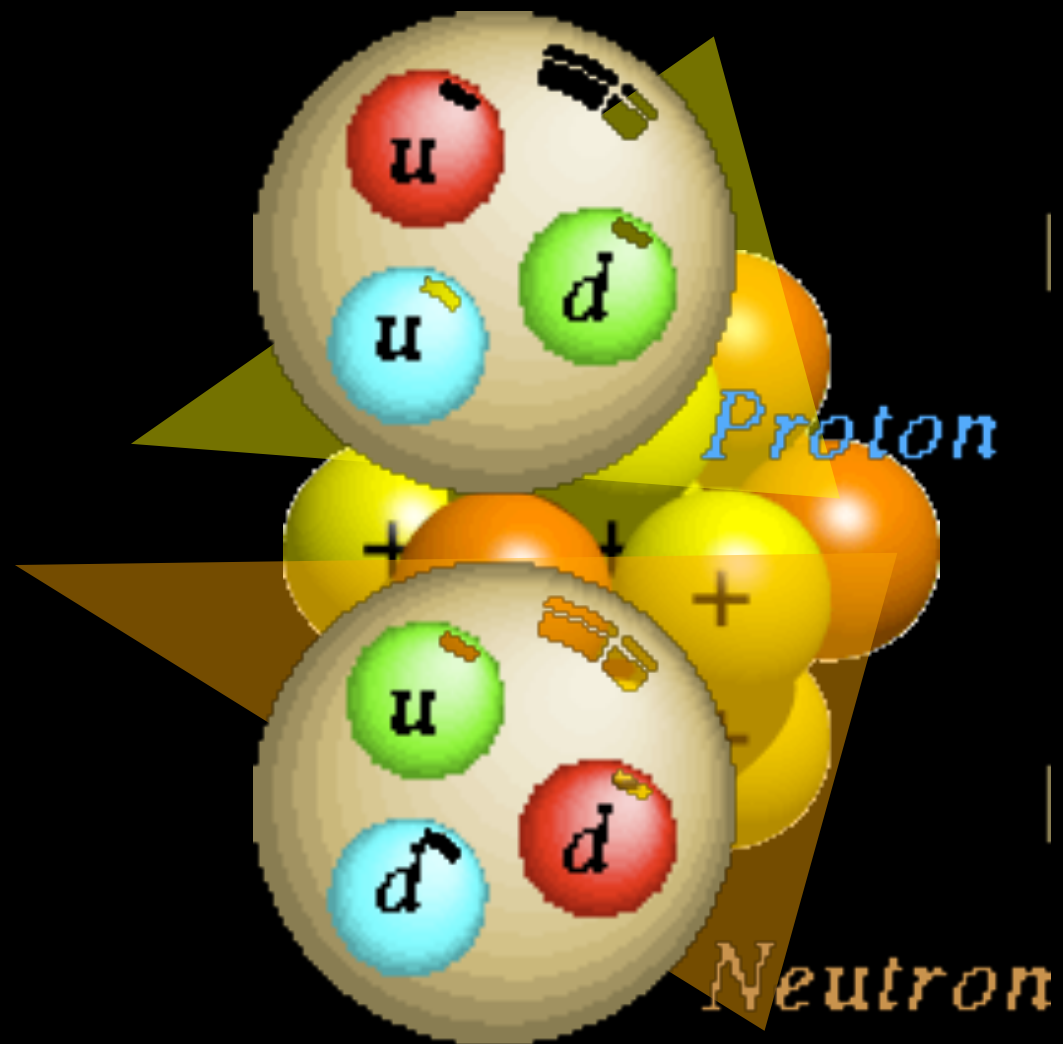
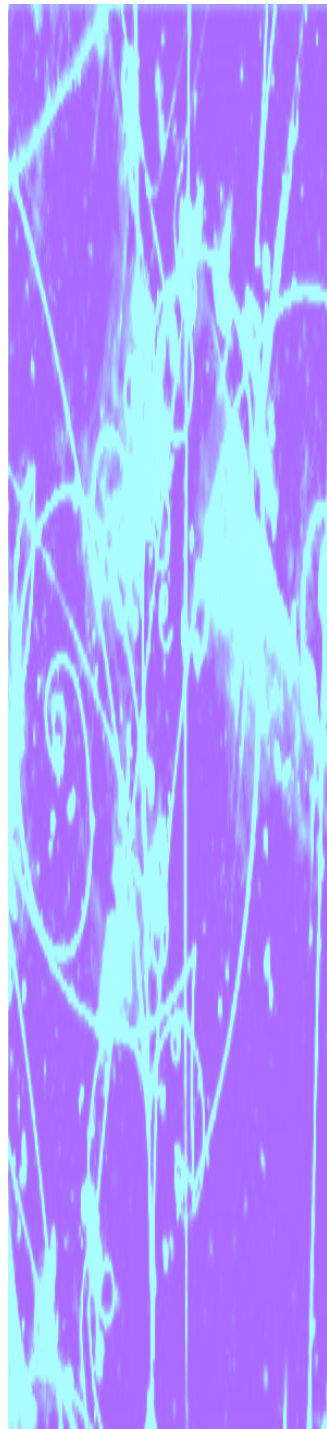



0.06

0.2

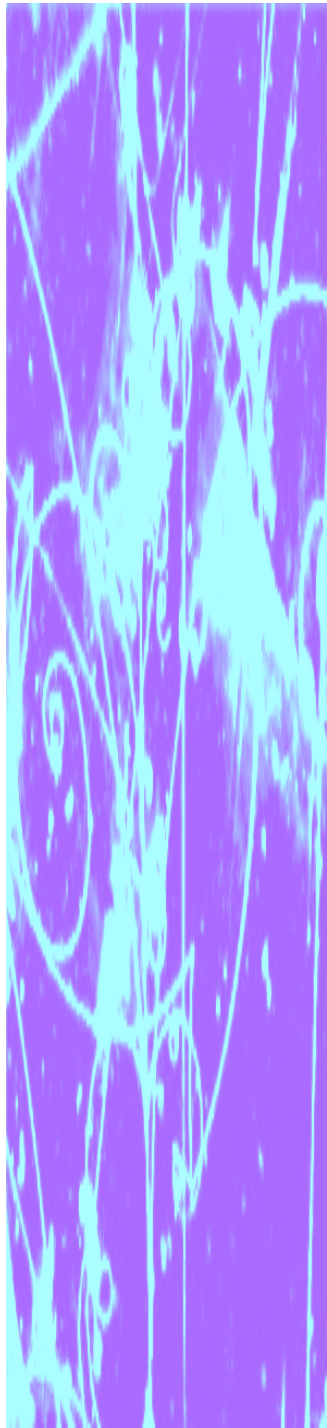
1

millimetres nanometre femtomet






**“Langdon
noticed a man in
a wheelchair
exiting the
building....he
wore a white lab
coat.....”**



Robert Aymar, Dir

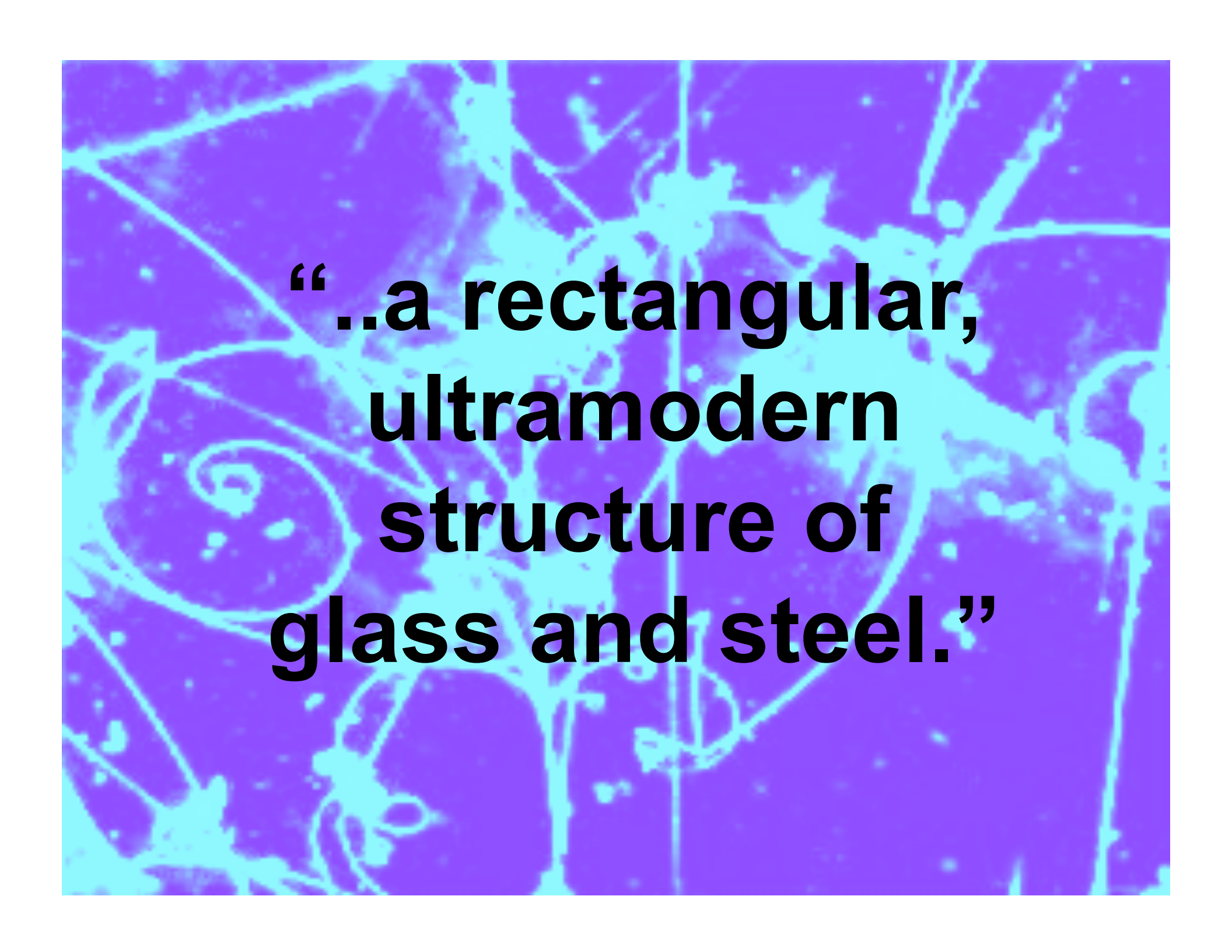
**Maximilian Metzger,
Secretary General**





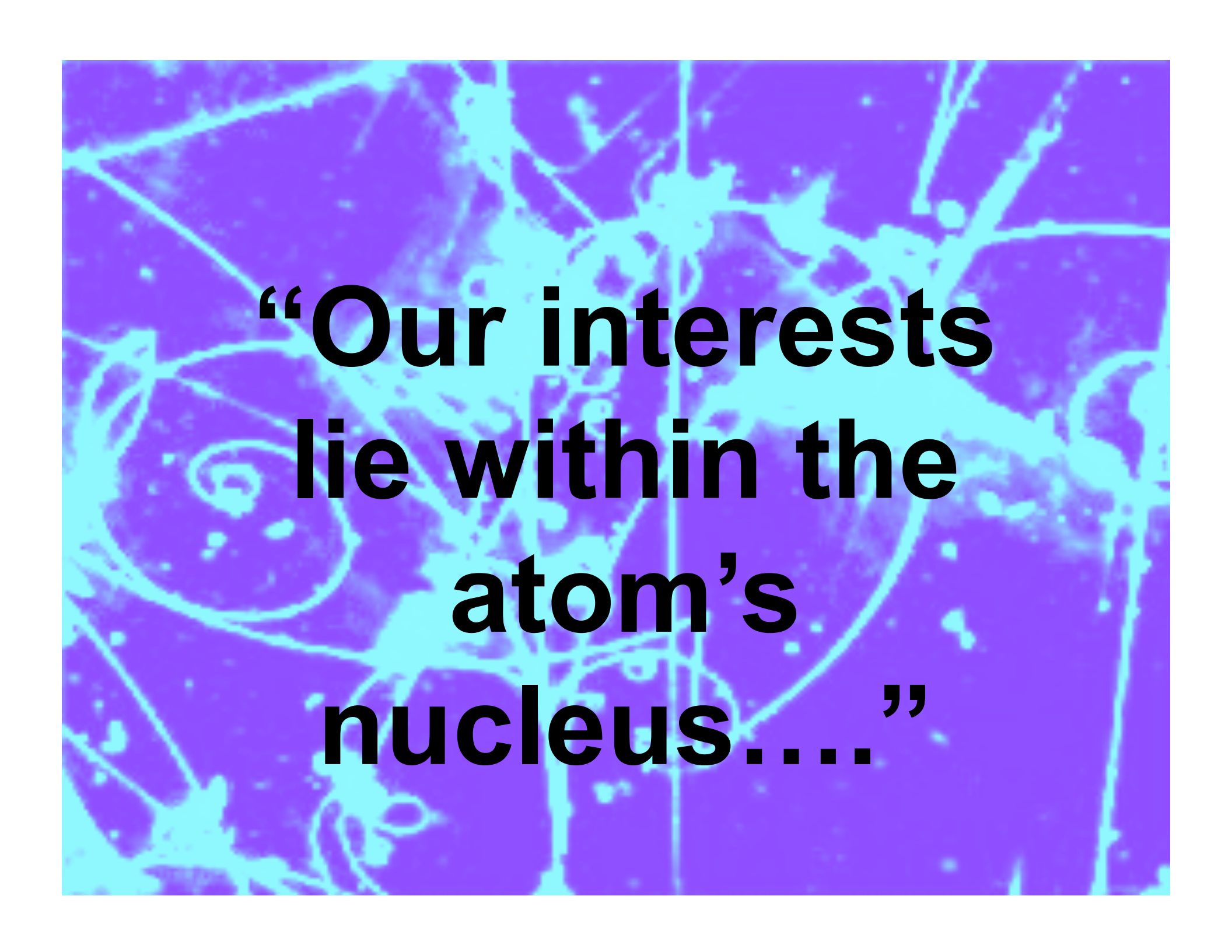
“Passports are unnecessary. We have a standing arrangement with the Swiss government.”





**“..a rectangular,
ultramodern
structure of
glass and steel.”**





**“Our interests
lie within the
atom’s
nucleus....”**

A vertical decorative bar on the left side of the slide, featuring a complex, abstract pattern of white and light blue lines and shapes against a dark blue background, resembling a microscopic view or a particle detector's output.

So what IS CERN?

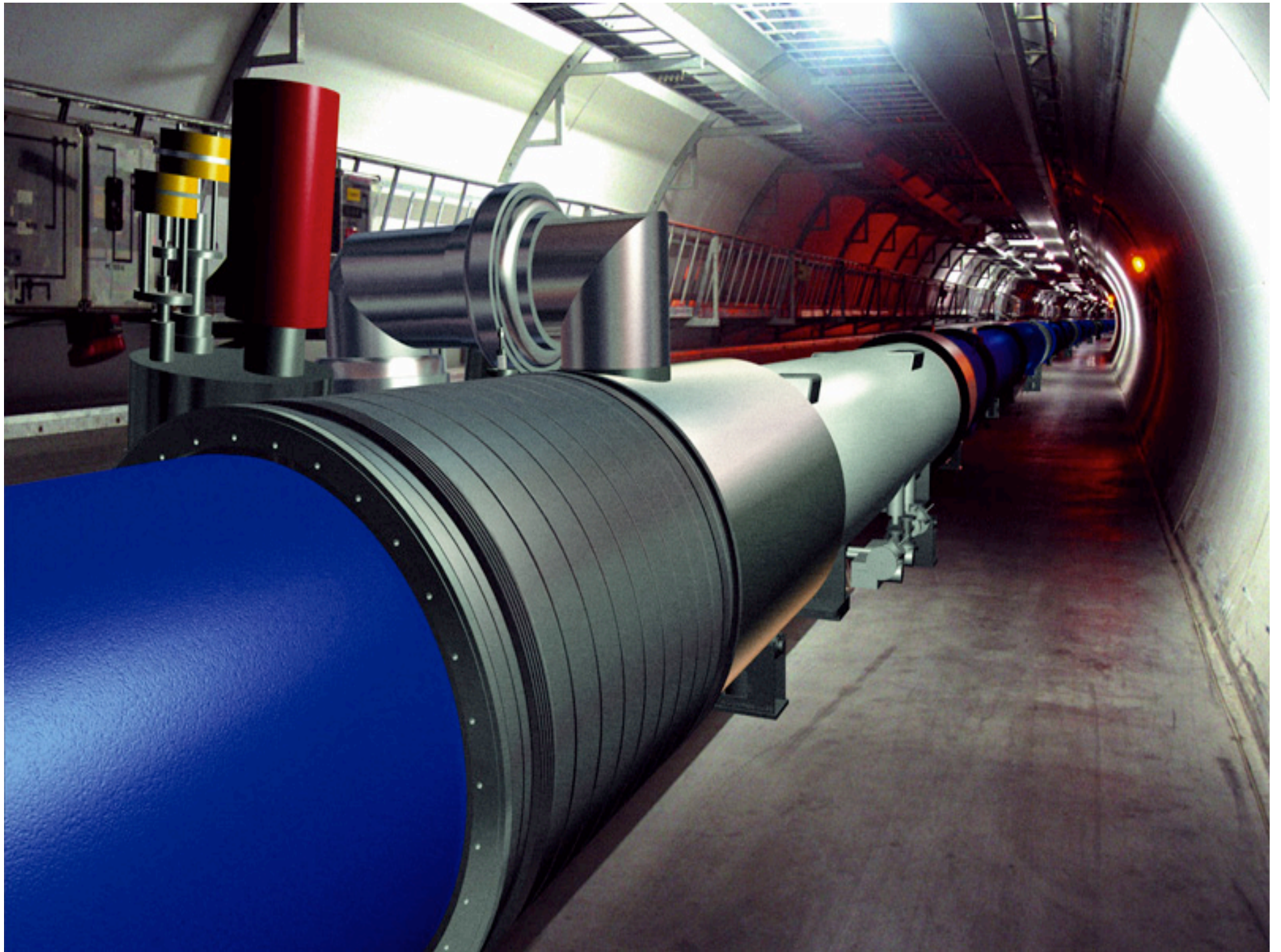
- **The European Organization for Nuclear Research TRUE**
- **The world's largest scientific research facility TRUE**
- **Physicists from 20 Member States in Europe come to explore what matter is made of and what forces hold it together.**
- **Founded in 1954, the laboratory was one of Europe's first joint ventures.**



**More than 6,500
physicists work at
CERN, representing
over 500 universities
and 85 nationalities.**









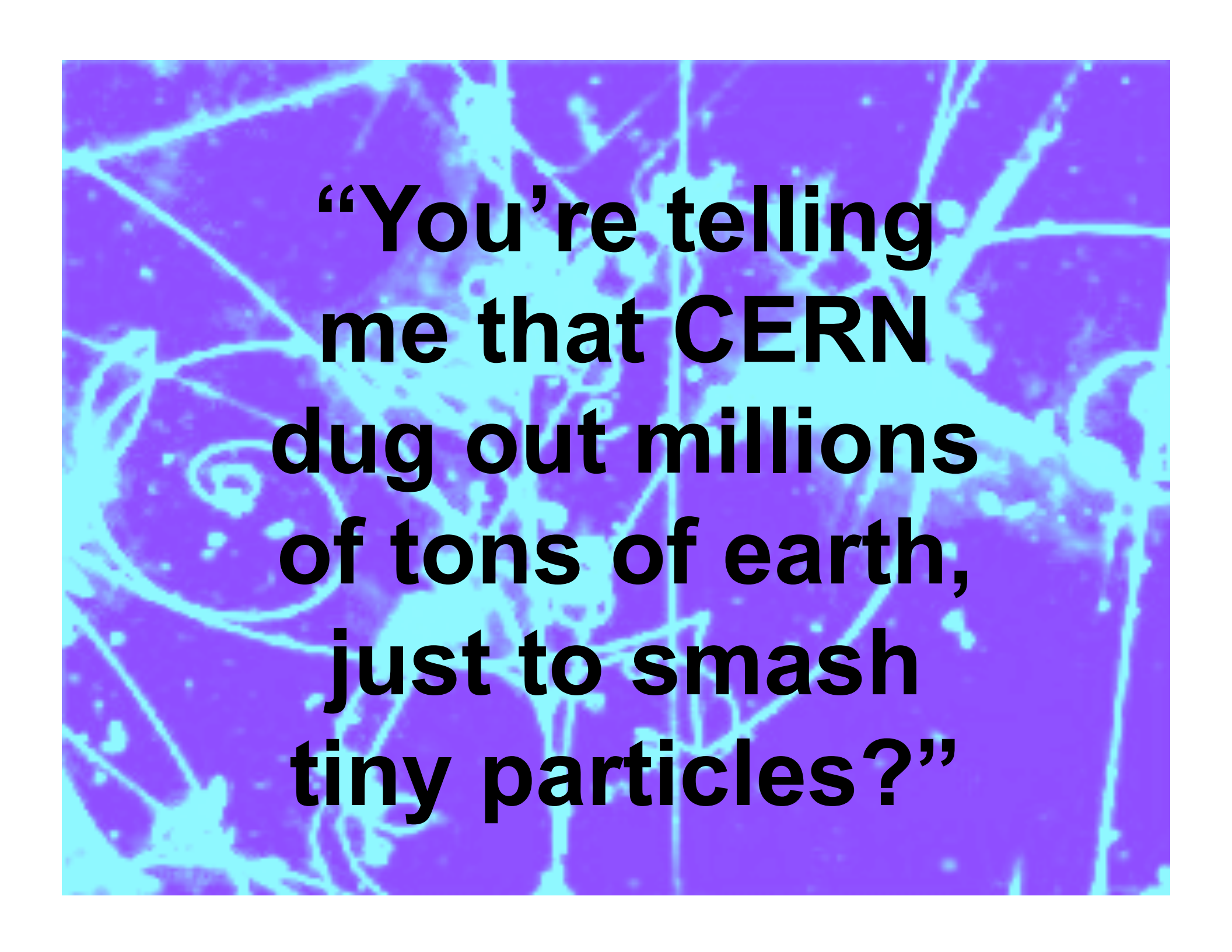
**“What’s LHC
stand for?...**

**Langdon asked,
trying not to
sound
nervous....”**

...the Large Hadron Collider

- **The LHC will be the world's most powerful particle accelerator.**
- **It will smash beams of protons into each other, to find new particles and new science.**



The background of the slide is a dark, textured image showing numerous bright, glowing lines and points of light, resembling particle tracks or a complex network of connections. The lines are primarily yellow and white, with some blue and green highlights, set against a dark, almost black background.

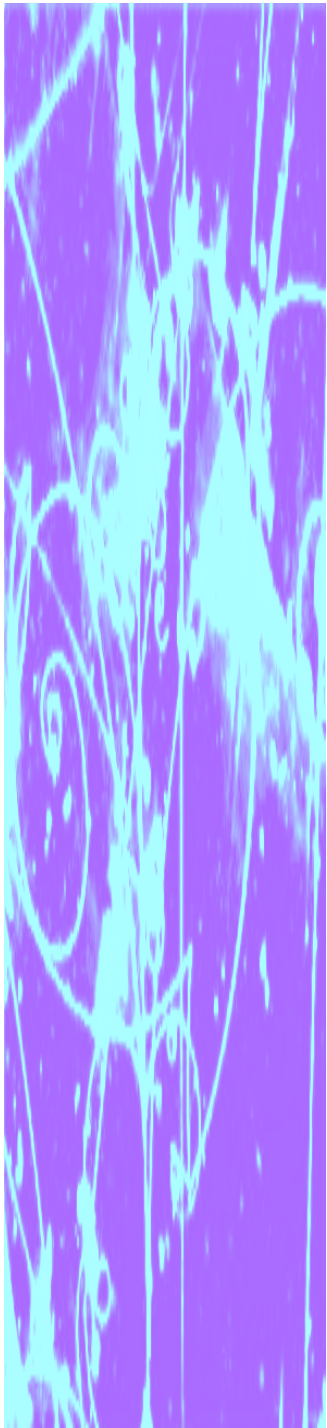
**“You’re telling
me that CERN
dug out millions
of tons of earth,
just to smash
tiny particles?”**

An abstract, vertical rectangular image on the left side of the slide. It features a dark blue background with intricate, glowing white and light blue patterns that resemble particle tracks or complex mathematical structures.

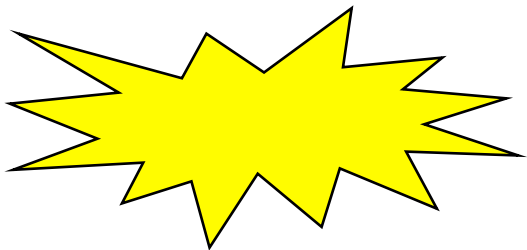
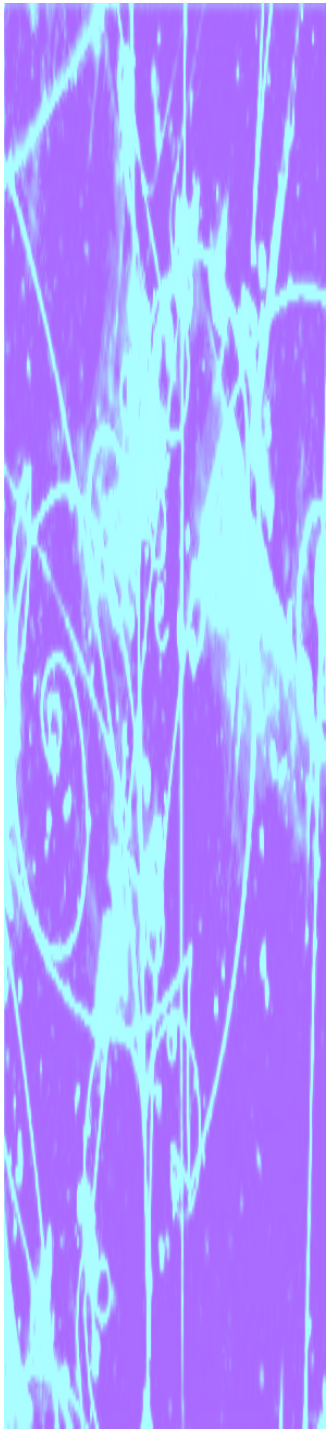
...YES!

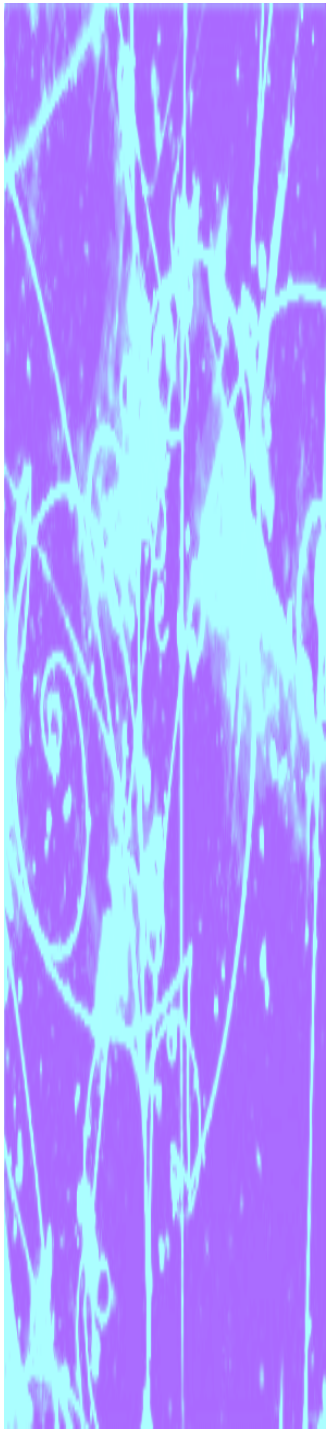
**At switch-on in
2007 the LHC
will provide the
highest ever
energies created
in a laboratory,
re-creating the
conditions
billionths of a
second after the
Big Bang**



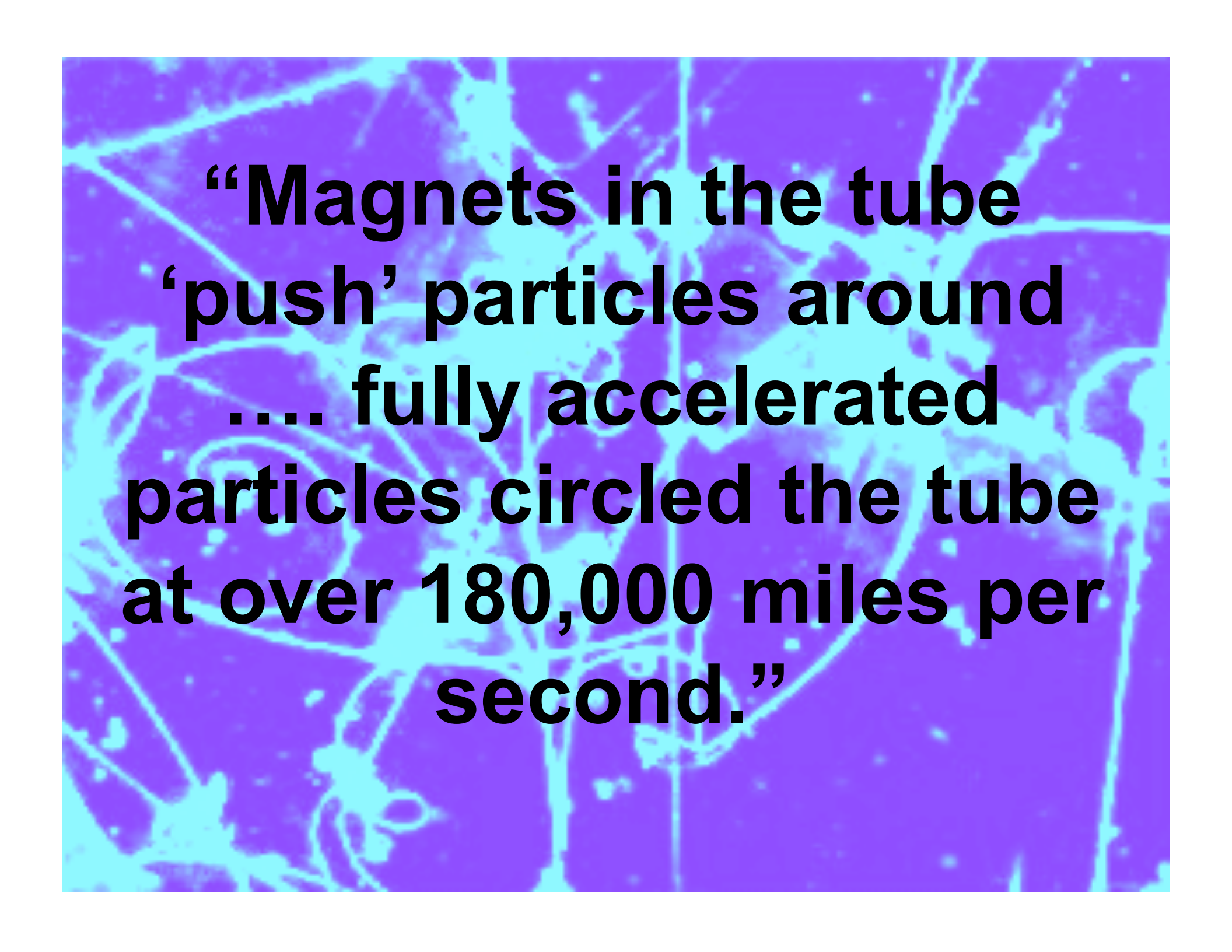


- **Particle energies are measured in electronvolts (eV).
1 eV is the amount of energy an electron gains when it moves through an electric field of one volt.**
- **Two protons colliding in the LHC will have an energy of 14 TeV.
14,000,000,000,000 eV**
- **Sounds big? 1 TeV is roughly the energy of.....**





- **A proton is about a billion times smaller than a mosquito.**
- **So at full power, each beam will be about as energetic as a car travelling at 2100 kph.**
- **The energy stored in the magnetic fields will be even greater, equivalent to a car at 10 700 kph.**



**“Magnets in the tube
‘push’ particles around
.... fully accelerated
particles circled the tube
at over 180,000 miles per
second.”**

A vertical rectangular area on the left side of the slide featuring a complex, abstract pattern of white, branching, and swirling lines against a solid blue background, resembling a microscopic view or a stylized representation of particle paths.

...almost...

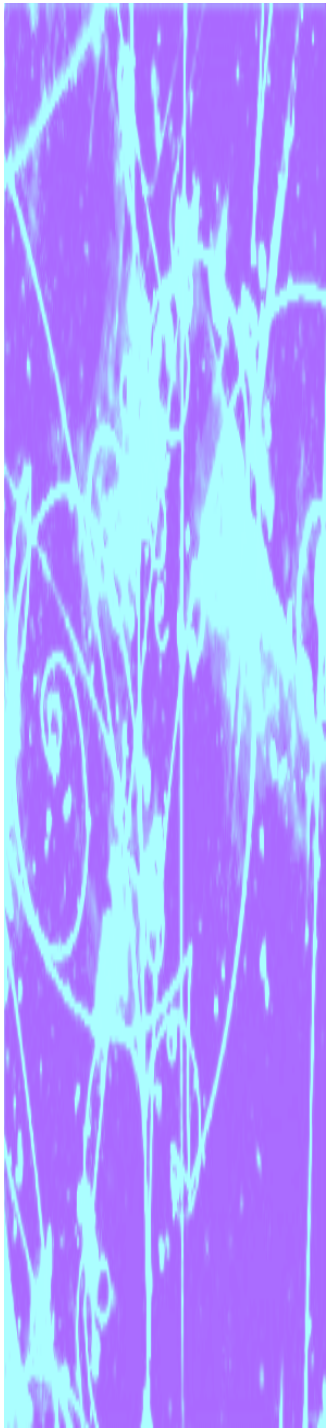
- **180,000 miles per second is the speed of light. 300,000,000 metres per second. Universal speed limit.**
- **A proton in the LHC will go round the 27km ring over 11,000 times a second.**
- **Beam life up to 10 hours, covering more than 10 billion kilometres. To Neptune and back!**
- **BUT – magnets ARE used to ‘push’ the particles around...**



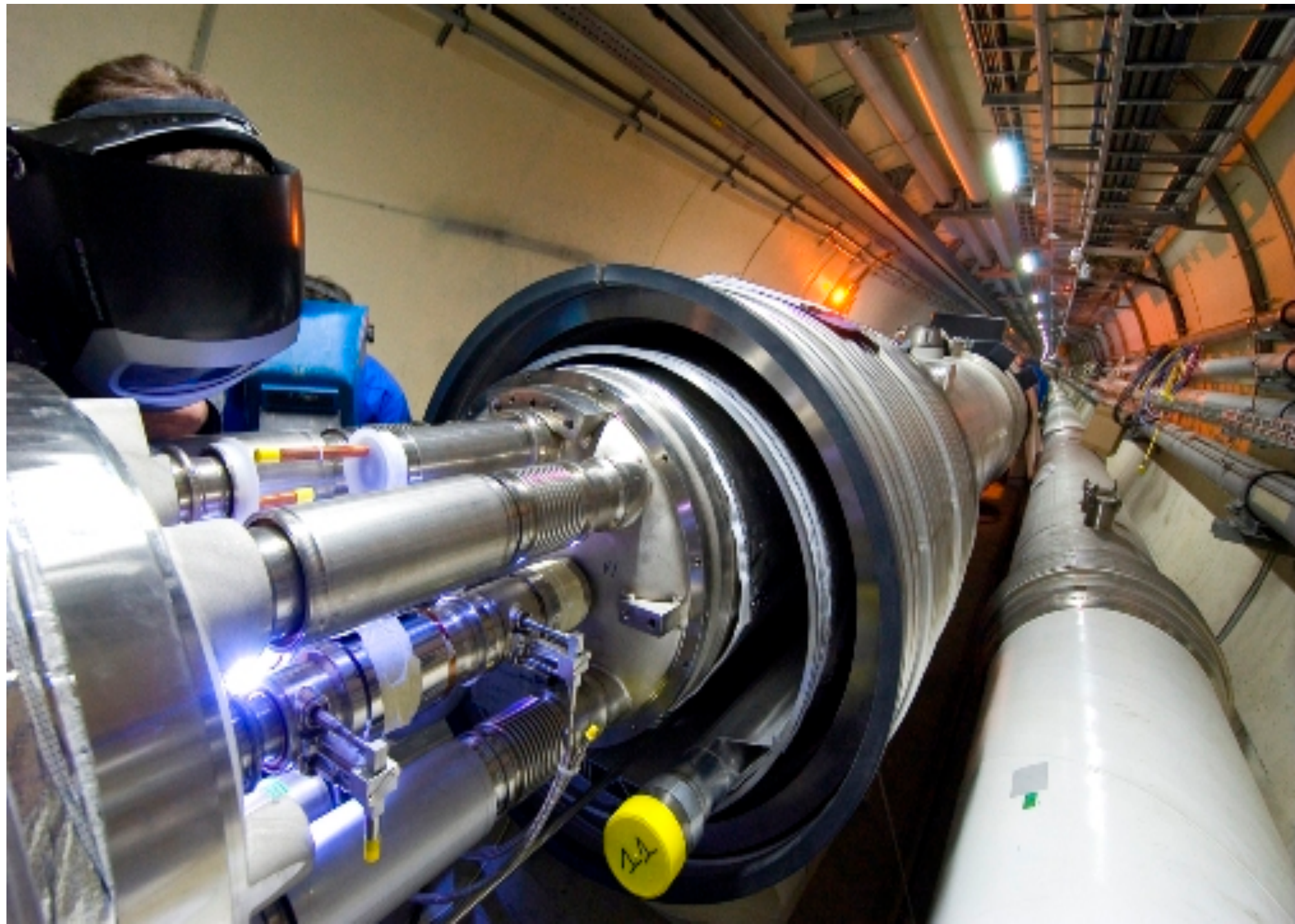
...supercooled magnets..

To control particle beams at high energies the LHC uses around 1200 superconducting magnets.



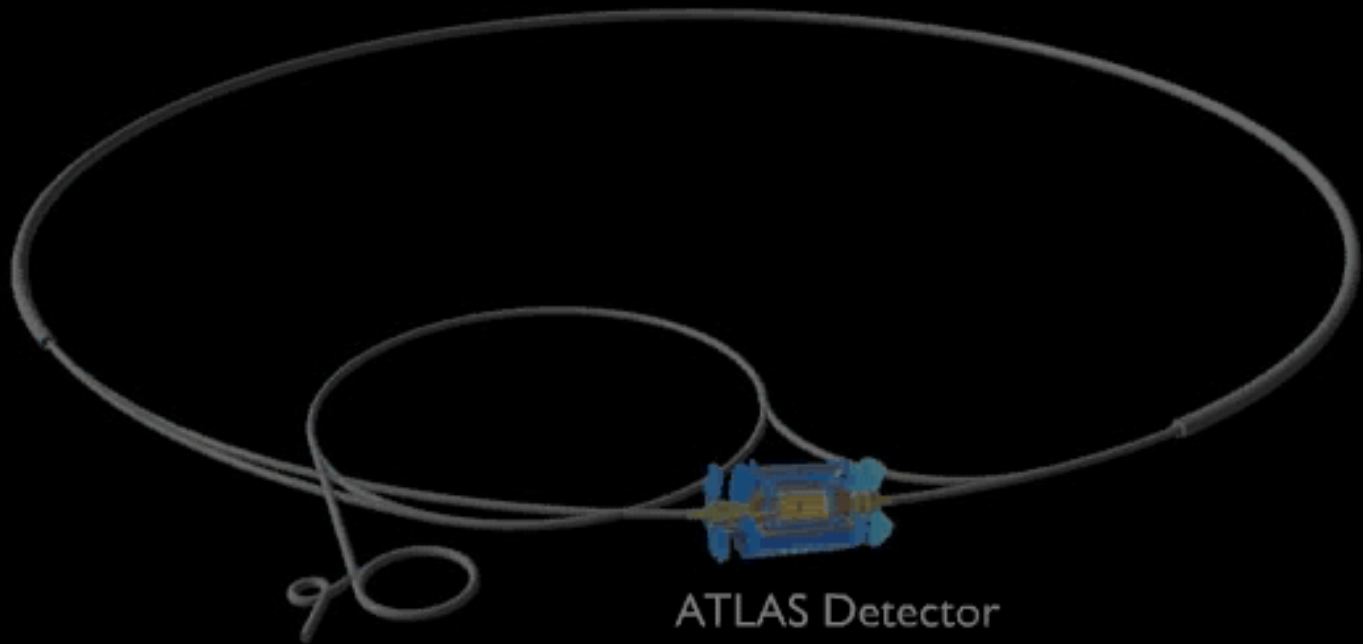


- **Why magnets?**
Charged particles move in an magnetic field, so the particle beam can be “bent” round the 27km ring using very strong magnets.
- **Superconducting materials allow electricity to flow without resistance at very low temperatures.**
- **More electric current = higher magnetic fields.**
- **Minus 270 degrees celsius, only 3 degrees above absolute zero.**
- **8 Tesla = 200,000 times the Earth’s magnetic field.**

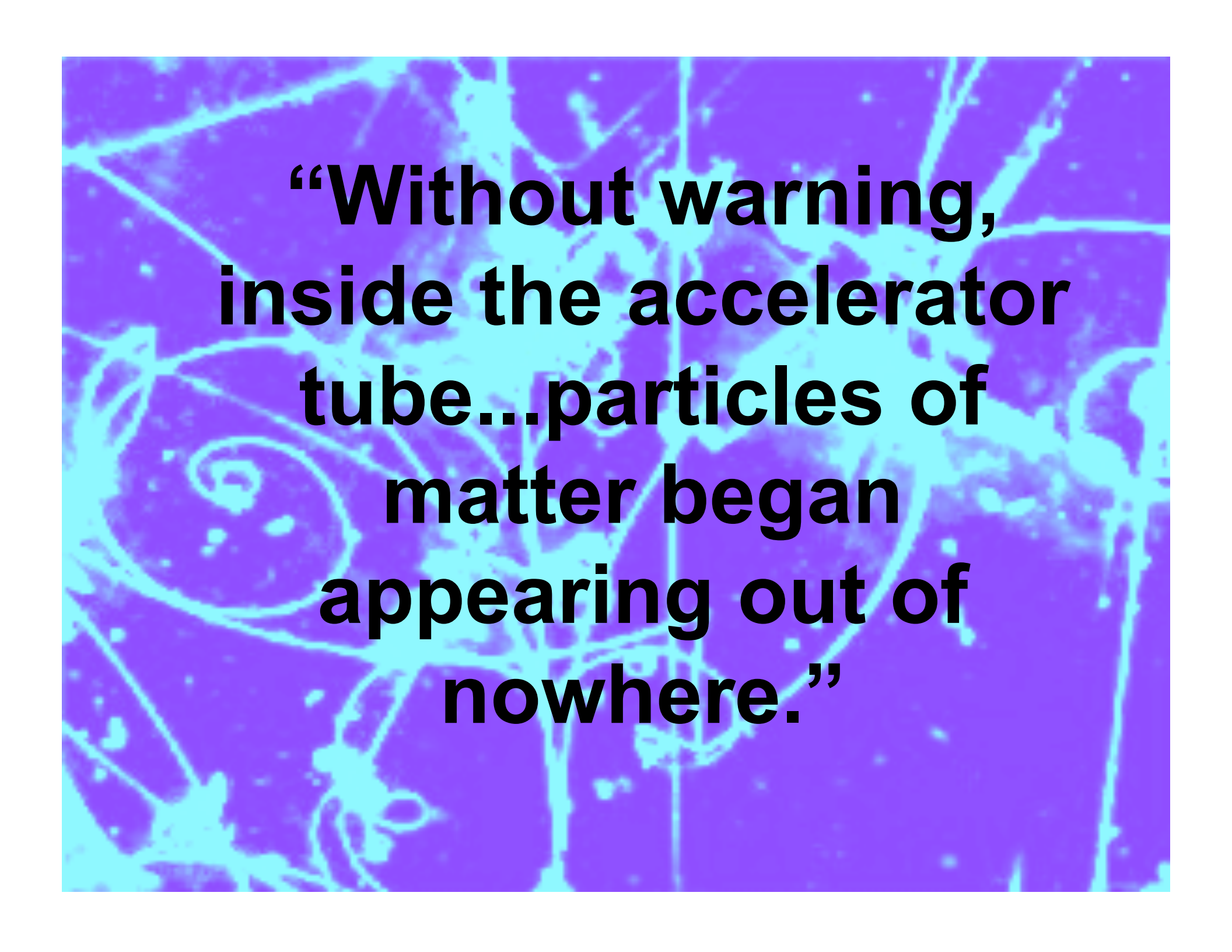


PLAY ▶

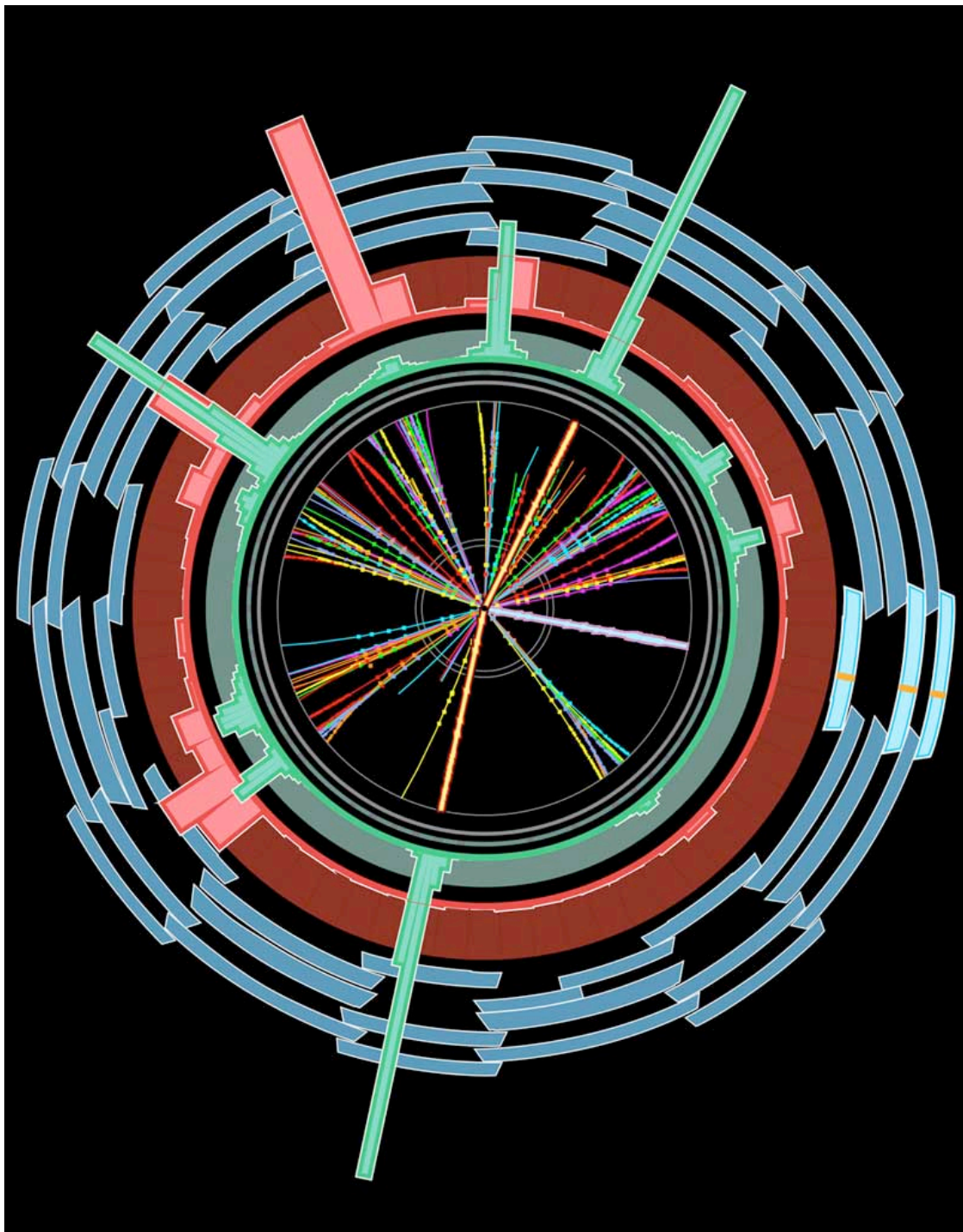
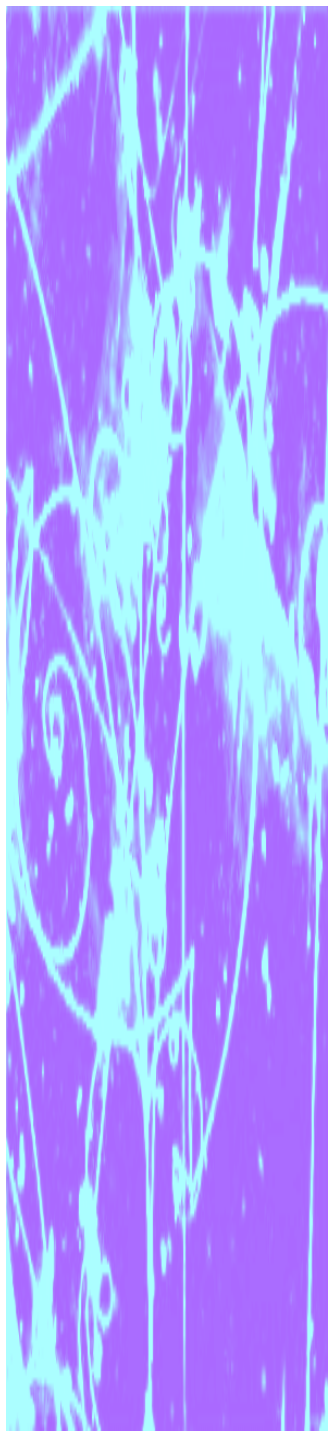
Large Hadron Collider

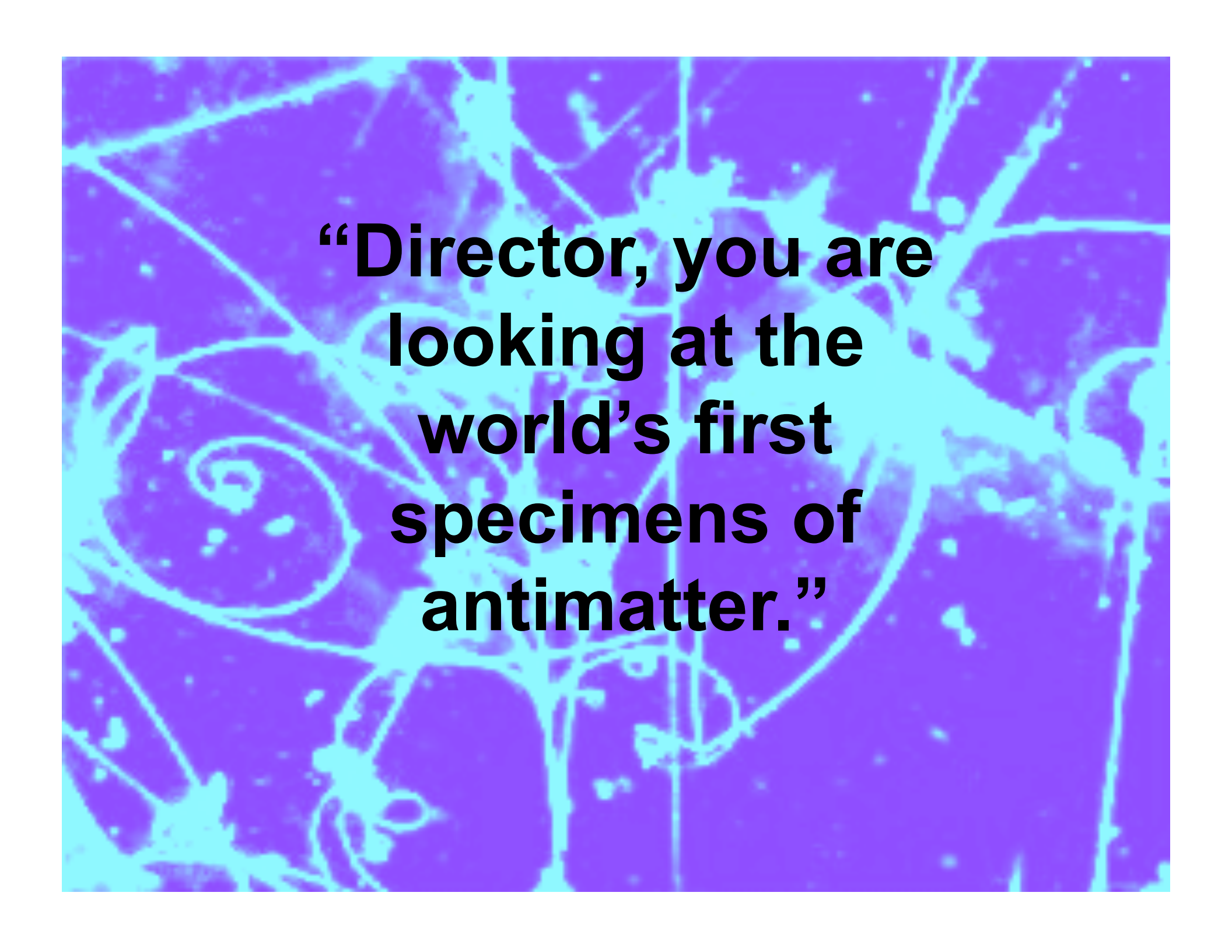


ATLAS Detector



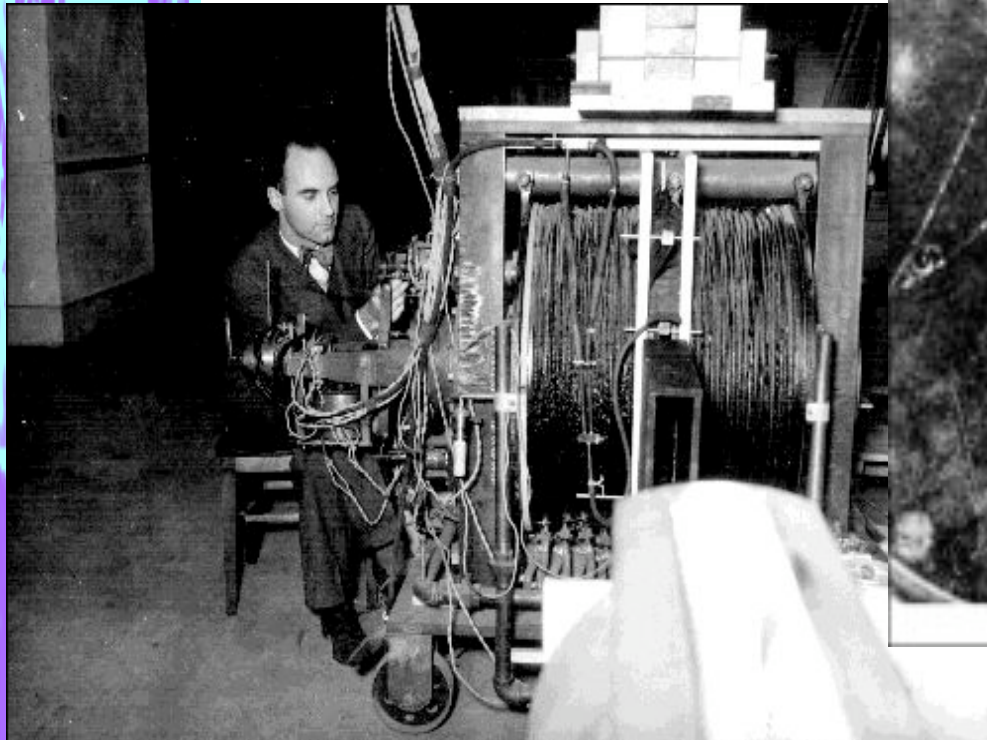
**“Without warning,
inside the accelerator
tube...particles of
matter began
appearing out of
nowhere.”**



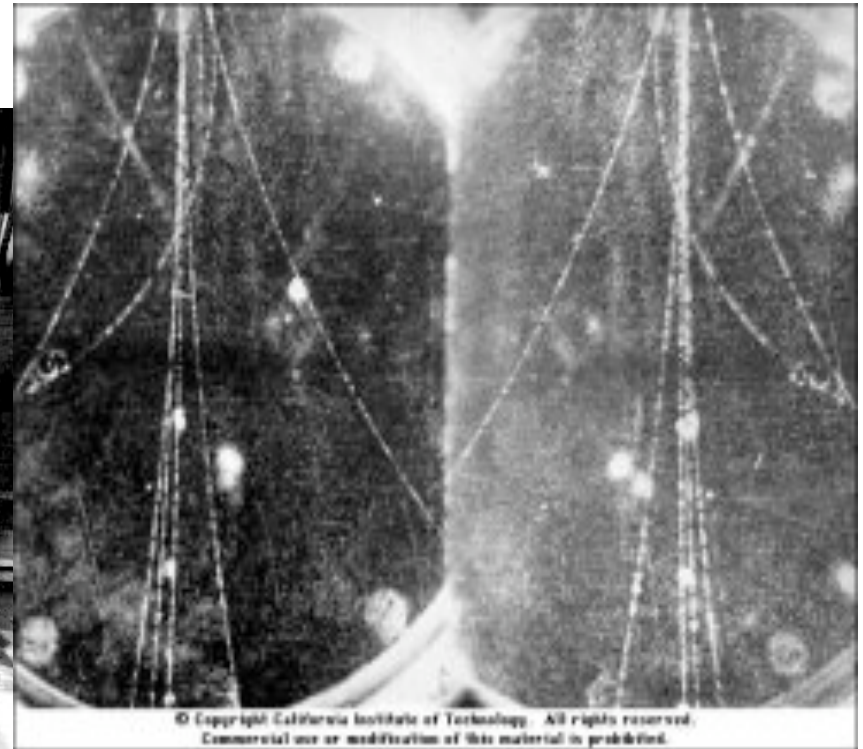
The background of the slide is a complex, abstract pattern. It features a grid of small, light blue dots. Overlaid on this grid are several large, swirling, and branching patterns in shades of blue and green. These patterns resemble biological structures like neurons or perhaps abstract representations of particle paths. The overall effect is a high-tech, scientific aesthetic.

**“Director, you are
looking at the
world’s first
specimens of
antimatter.”**

The world's first specimens of antimatter were actually created in 1932 in California.



© Copyright California Institute of Technology. All rights reserved.
Commercial use or modification of this material is prohibited.

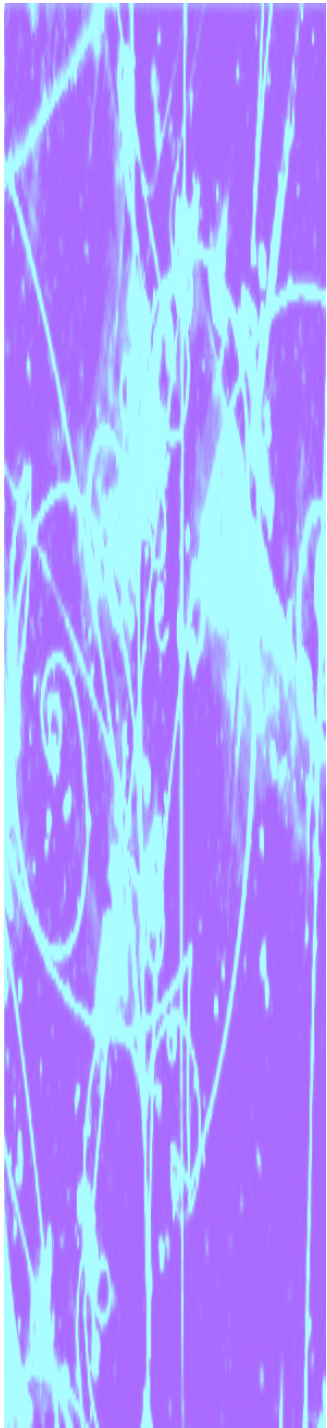


© Copyright California Institute of Technology. All rights reserved.
Commercial use or modification of this material is prohibited.



““Annihilation?”

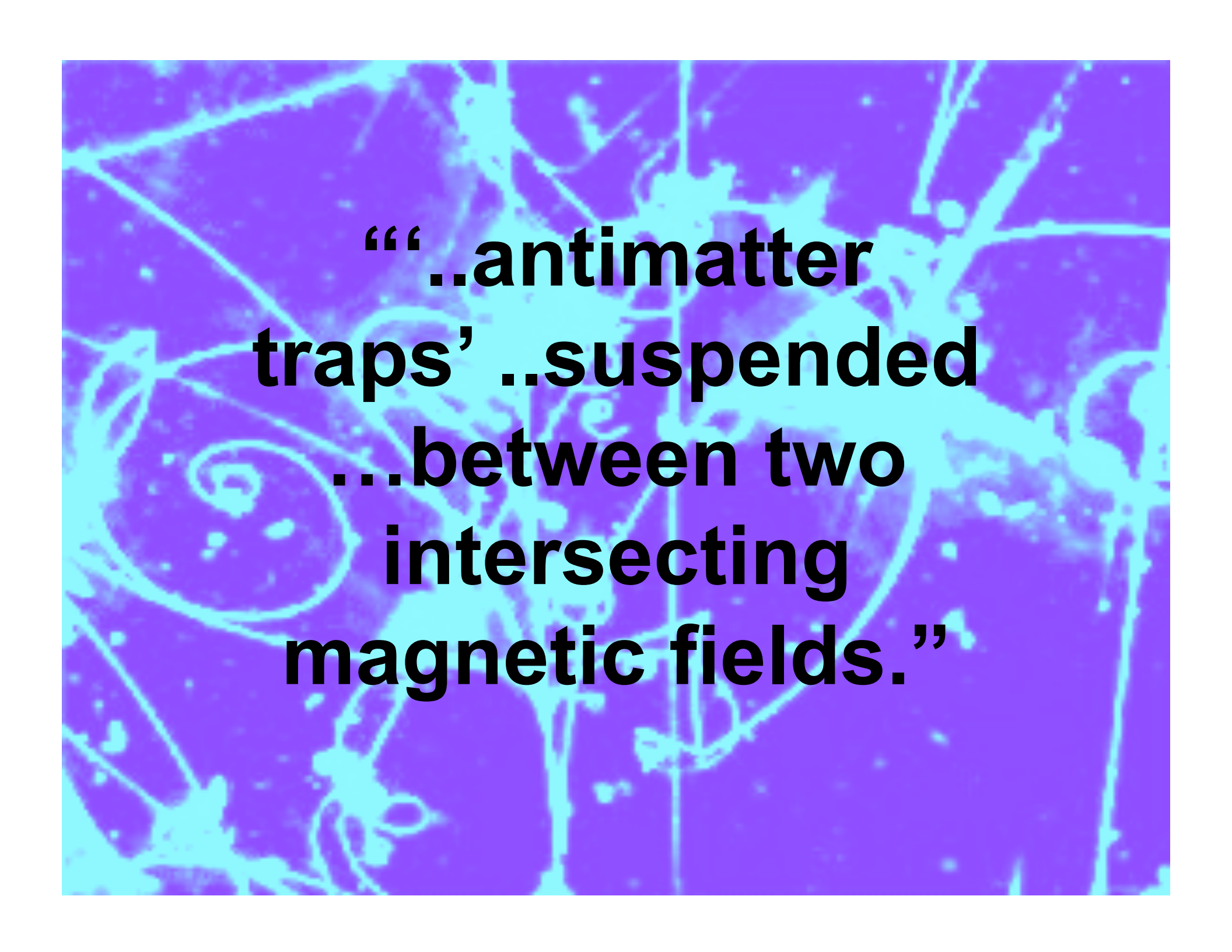
**He didn't like the
sound of it.”**



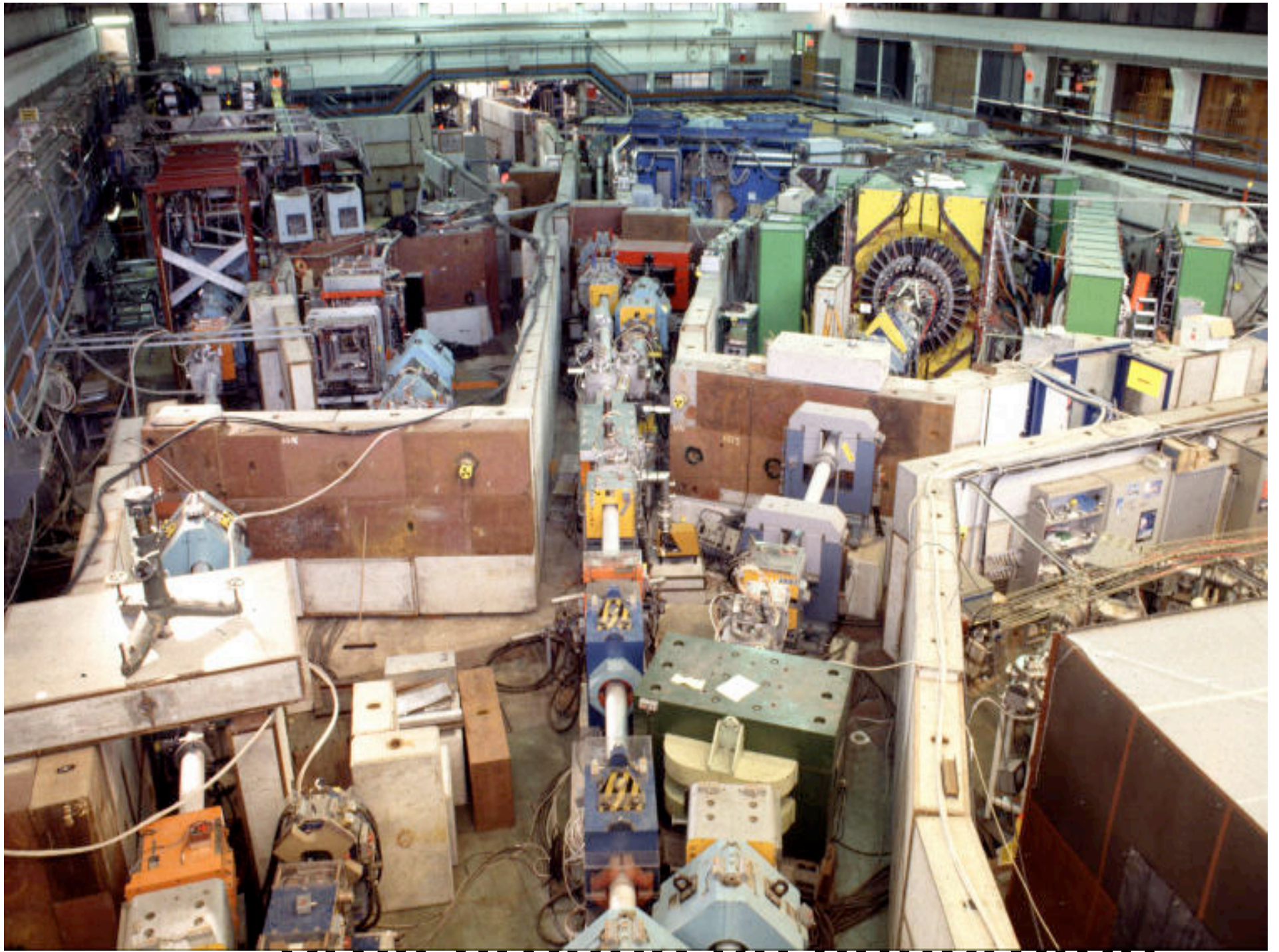
- **When antimatter comes into contact with matter it annihilates.**
- **Converts 100% of its mass into pure energy.**

$$E=mc^2$$

- **Mystery – we owe our existence to an asymmetry between matter and antimatter.**
- **Universe is entirely matter.....or entirely antimatter!**



**“‘..antimatter
traps’ ..suspended
...between two
intersecting
magnetic fields.”**



Orbit around an antiproton.

A vertical rectangular area on the left side of the slide featuring an abstract, swirling pattern of white and light blue lines against a dark blue background.

...antimatter traps...

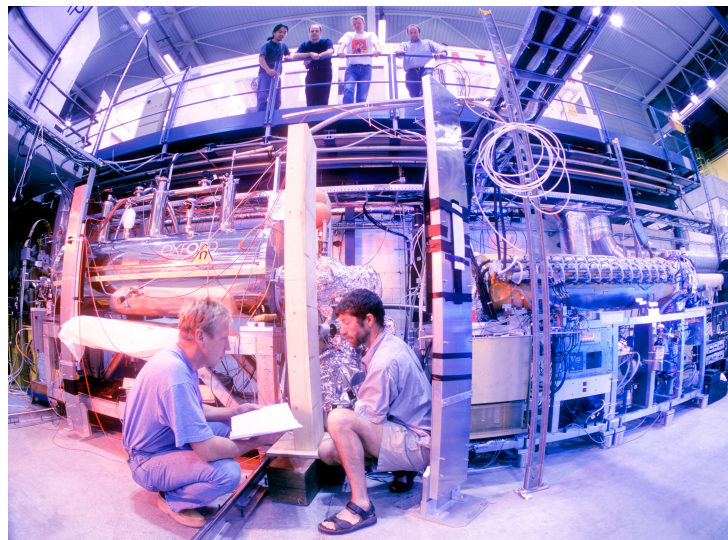
- **BUT, the anti-hydrogen atoms were not trapped. They were produced in flight - moving at nearly the speed of light.**
- **Too fast to allow precise measurements on any of their properties!**
- **Today CERN uses the Antimatter Decelerator to slow down the antimatter and make measurements on it.**

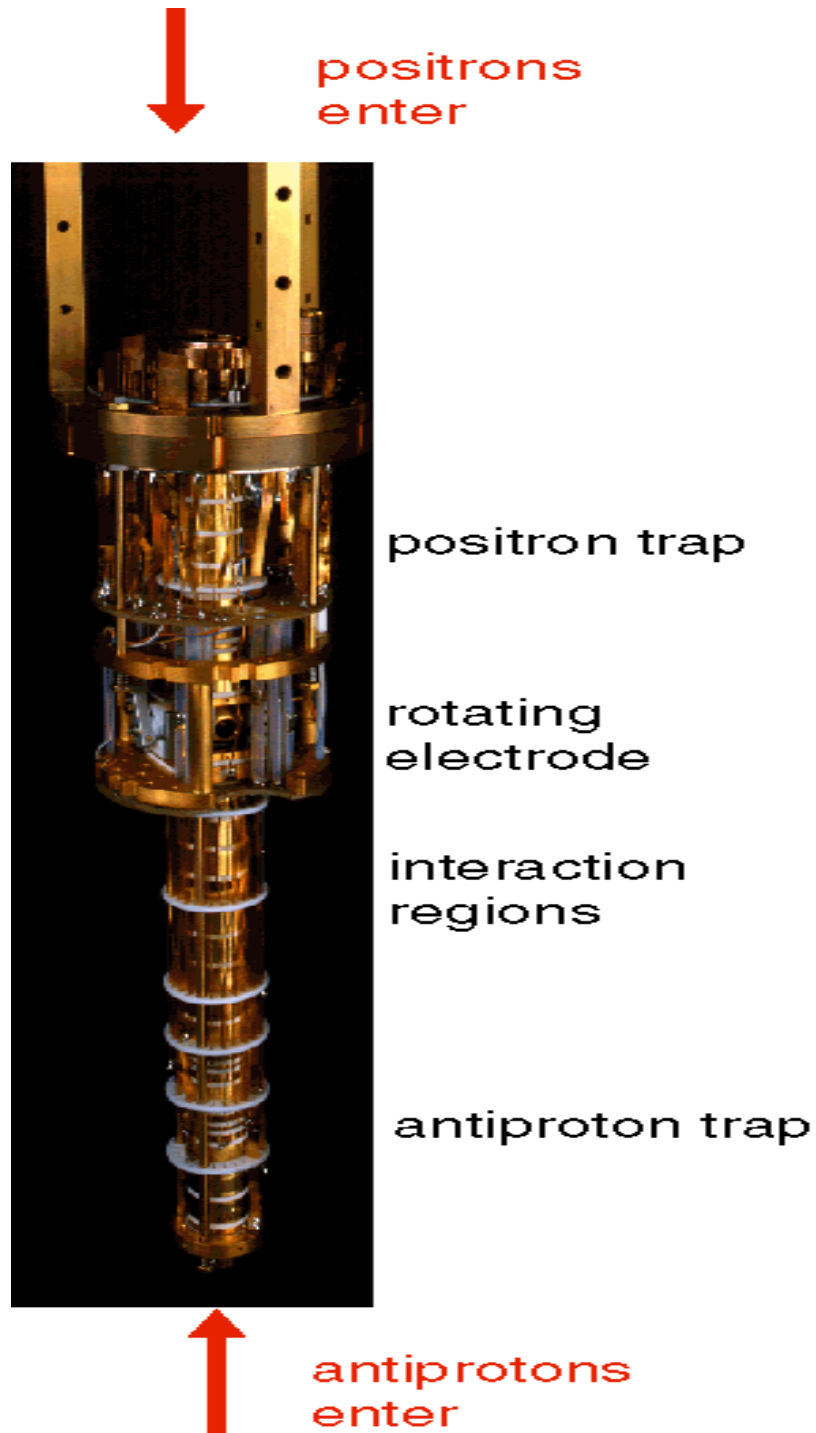
“My father built a reverse polarity vacuum to pull the antimatter positrons out of the accelerator before they could decay.”



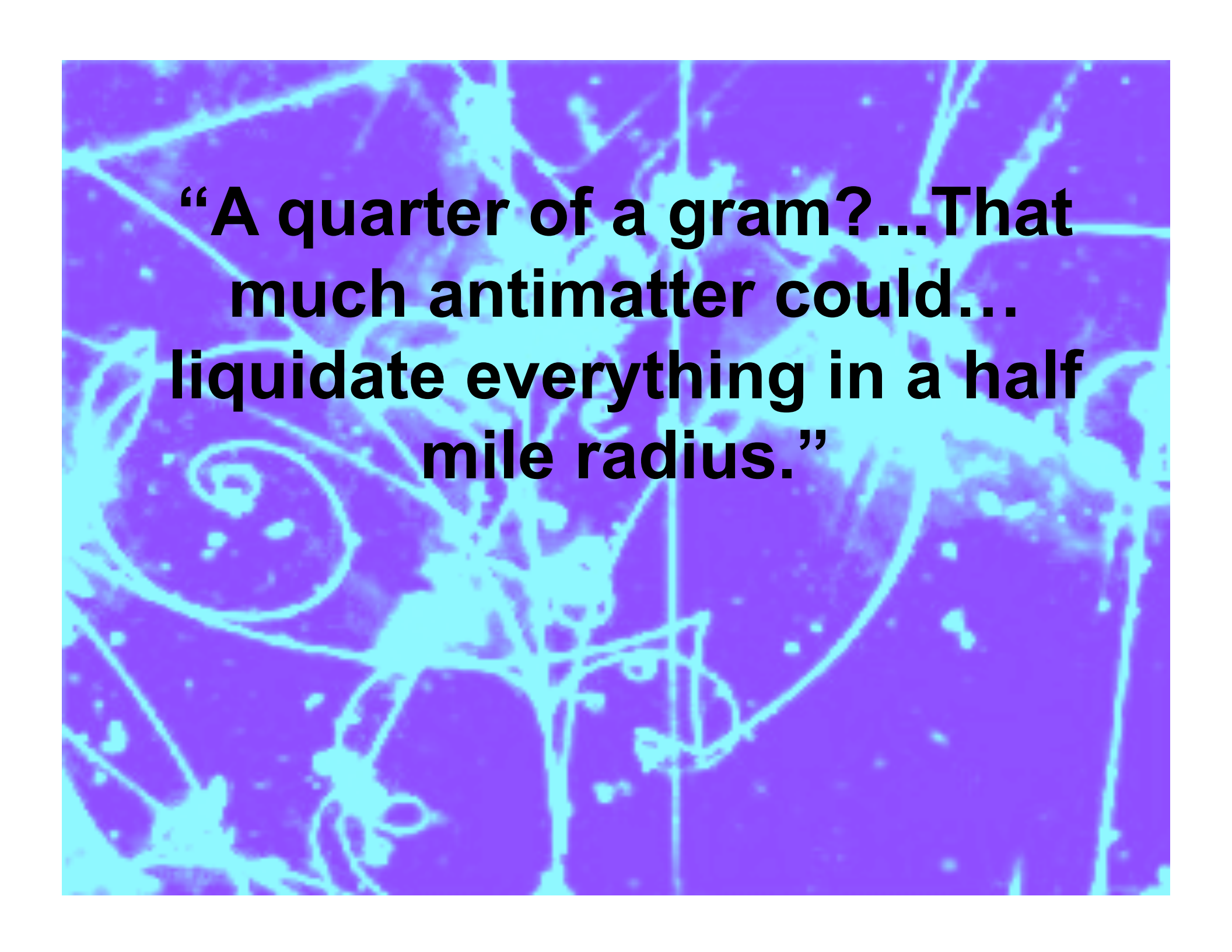
...antimatter traps...

- **The Antiproton Decelerator ring has a circumference of 188 m.**
- **Vacuum pipe and vacuum pumps**
- **Magnets**
- **Radio-frequency cavities, high voltage instruments and electronic circuits.**

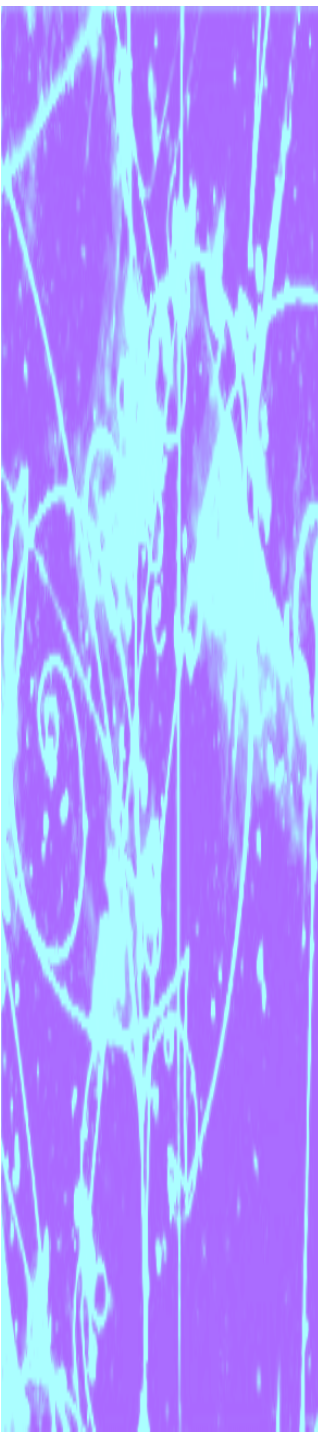




- Latest experiment uses the world's most intricate antimatter trap.
- Long series of gold-plated electrodes, cooled to minus 269 degrees C, in a 6 Tesla magnetic field.
- Not very portable!



**“A quarter of a gram?...That
much antimatter could...
liquidate everything in a half
mile radius.”**

- 
- $E = mc^2$
 - $E = 1/4g \text{ antimatter} \times (\text{speed of light})^2$
 - $E = 22,500 \text{ TJ}$
 - So if $4.2 \text{ TJ} = 1 \text{ kiloton of TNT}$,
then:
 $22,500 \text{ TJ}$, corresponds to
 $22,500/4.2 = 5 \text{ kilotons}$.
About right.

An abstract, vertical image on the left side of the slide. It features a dark blue background with intricate, white, branching patterns that resemble lightning or a complex network of fibers. The patterns are more dense and bright in the upper half and become sparser towards the bottom.

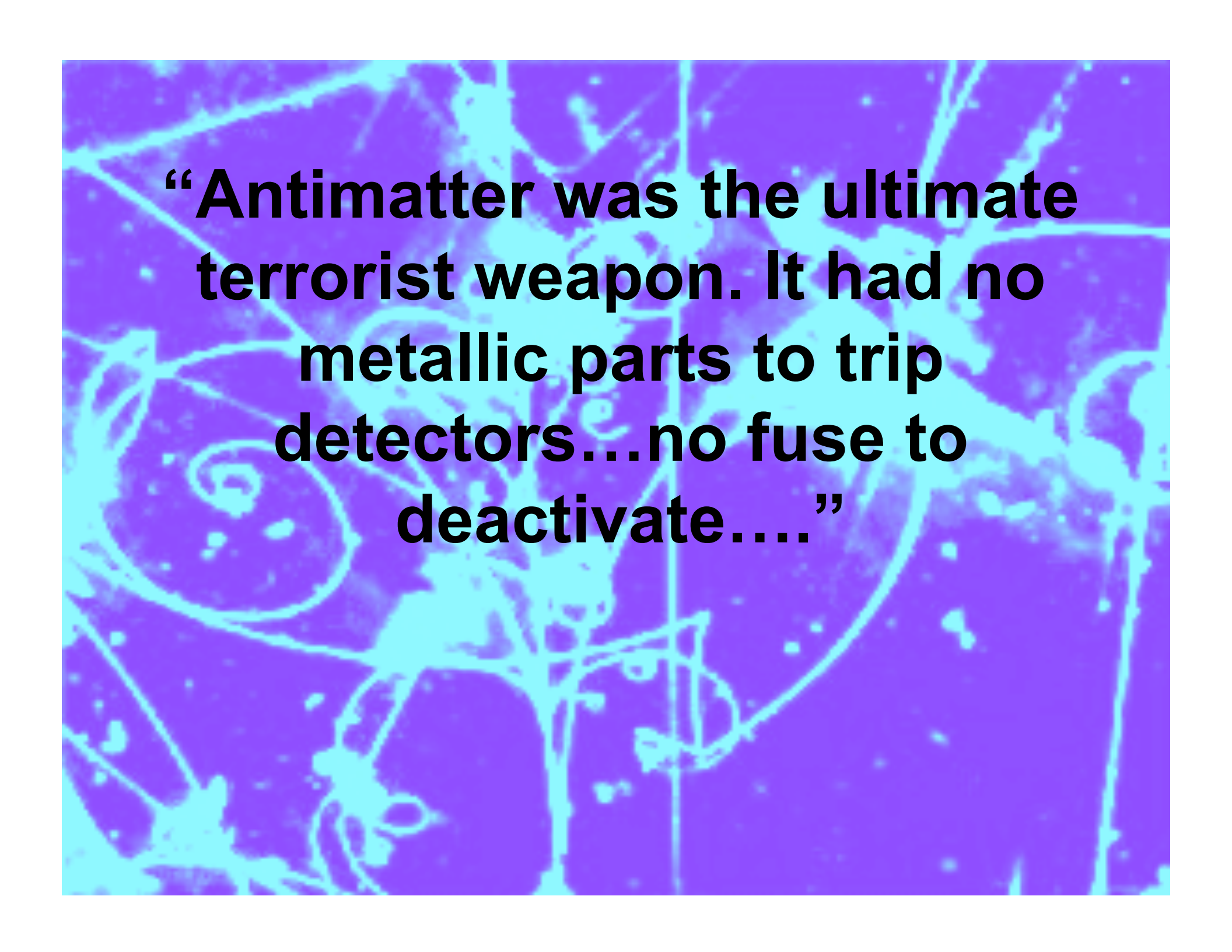
But, for the antimatter bomb we are actually talking about :

**1/4 gram of antimatter,
annihilating with 1/4 gram of
normal matter.**

**So you release the energy
associated with half a gram,
which is**

10,000 kilotons.

**So you only need twice that,
which is half a gram of
antimatter, to be as destructive
as the Hiroshima bomb.**



“Antimatter was the ultimate terrorist weapon. It had no metallic parts to trip detectors...no fuse to deactivate....”



....definitely not true..

- **The Antimatter canister traps, if they were portable, are made of metal, and would trip detectors.**
- **More crucially, we will never make enough antimatter for a “bomb.”**

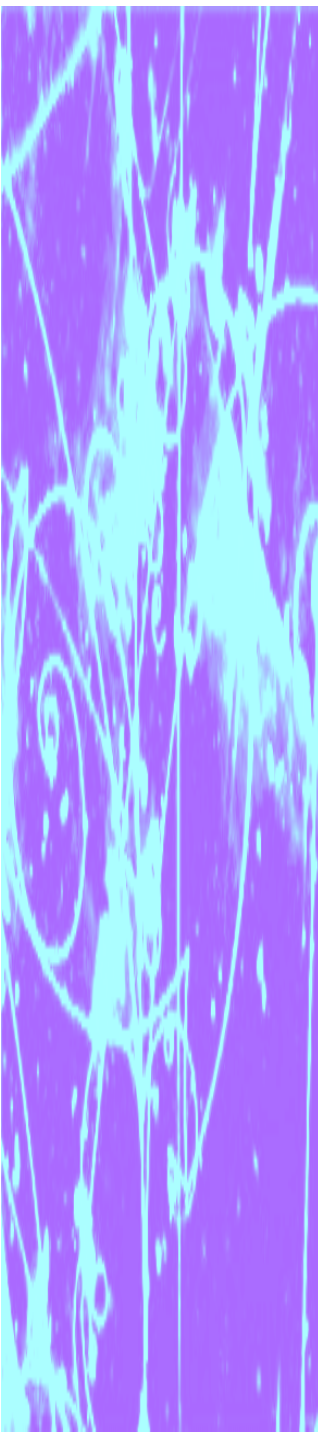
A vertical rectangular area on the left side of the slide featuring an abstract, swirling pattern of white and light blue lines against a dark blue background.

CERN makes around 100,000,000 antiprotons per second.

There are 6×10^{23} antiprotons in a single gram of antihydrogen.

$$6 \times 10^{23} \text{ divided by } 100,000,000 = 6 \times 10^{16}$$

So we would need 6×10^{16} seconds to make a gram of antimatter.



There are only
 $365 \times 24 \times 60 \times 60 = 3 \times 10^7$
seconds in a year

So when you divide 6×10^{16}
by 3×10^7 you find it will take
roughly 2×10^9 seconds,
which is about

2 thousand million years!

